REMARKS

Claims 1-3 and 6-25 remain in this application. Claims 4-5 have been canceled. Claims 1, 8, and 19 have been amended. By these amendments, no new matter has been added.

Prior to addressing the pending rejections of the claims, it may be helpful to briefly review certain innovative aspects of the invention. The invention concerns a computer-implemented method for photogrammetry or other reverse rendering problems, that has been implemented at a production level as a software tool. As such, the invention has proven to have significant advantages over prior art methods and tools for photogrammetry in a production environment, by providing substantially faster and more accurate solutions to photogrammetry problems.

One novel aspect of the invention involves the implementation of a solution algorithm that computes the full exact Hessian of an error function using automatic differentiation and generic programming, applying Newton's method to find the error minima in bundle adjustment. Previous approaches, e.g., Levenberg-Marquardt iterations or the the "sparse solver" approach described by Dellaert at pages 204-205, avoided an exact calculation of the Hessian. The present invention avoids the need to employ such approaches, which, whatever their theoretical merits, are difficult to program. Using automatic differentiation in a generic environment, programmers who are not experts in matrix manipulation and differential calculus can successfully program efficient solutions to bundle adjustment problems.

Another novel aspect of the invention concerns the use of scene graphs, which are a type of directed acyclic graph, to define an initial solution estimate. The scene graph organizes features of a scene in a hierarchical relationship. This is advantageous in manipulating objects in a scene generally. In addition, defining the initial solution for a photogrammetry bundle adjustment algorithm using scene graphs provides surprising benefits. These benefits include a dramatic reduction in the number of input images

needed to find a solution. By defining the initial solution estimate using a scene graph, it is possible to arrive at a solution using a much smaller number of input images. This capability may considerably ease the burden of gathering and inputting photogrammetry data for video production.

The invention thereby provides a robust and efficient computer-implemented method for solving photogrammetry bundle adjustment problems. Two unconventional approaches – employing the Newtonian solution method using the full Hessian calculated using automatic differentiation, and use of directed acyclic scene graphs as solution estimates – are combined and generate unexpected synergies to provide superior results.

The Examiner rejected Claims 1-25 under 35 U.S.C. § 102(b) in view of Dellaert. These rejections are respectfully traversed.

Dellaert discloses a Monte Carlo expectation-maximization algorithm, and its application to photogrammetry and machine vision problems. The Monte Carlo approach disclosed by Dellaert is unrelated to the present invention. Delleart also discusses various aspects of solving error-minimization problems, but the present invention employs different solution techniques than those disclosed in Delleart. Certain particular deficiencies of Dellaert are discussed below.

With respect to Claims 1 and 19, Delleart fails to disclose or suggest any use of directed acyclic scene graphs ("DAG's"). Delleart therefore does not and cannot disclose:

> receiving a first directed acyclic graph of the scene, the first directed acyclic graph defining transforms between hierarchically-related nodes of the graph;
>
> receiving user input indicating a plurality of corresponding features each appearing in at least two of the plurality of photographic images and associated with a node of the first directed acylic graph;

determining an error function for a reverse-rendering function, the reverse-rendering function defining a relationship consistent with the first directed acylic graph between three-dimensional coordinates in the three-dimensional scene and corresponding two-dimensional coordinates of the plurality of corresponding features;

as defined by Claims 1 and 19.

In paragraph 2e, the Examiner equated use of a JPDAF as disclosed at page 44 of Dellaert to receiving a scene graph comprising a transform between a parent object and a child object, as defined by former Claim 5. The Joint Probability Data Association Filter method or "JPDAF", is used in motion tracking applications to track multiple moving objects from 2-D vision data. JPDAF updates a target state for multiple moving targets weighted with associated posterior hypotheses from measurements in a current observation. JPDAF is a distinctly different technique from use of directed acyclic graphs to model a scene. Claims 1 and 19 define use of a scene graph or DAG to provide an initial solution estimate and guide the error minimization process. Unlike a DAG, a JPDAF does not provide a solution estimate with defined, hierarchical relationships between objects in a solution estimate. Such an approach would have no utility for real-time target-tracking applications for which JPDAF is designed. Instead, a JPDAF filters possible multiple-target solutions to 2-D vision estimates using probability estimates. Dellaert therefore fails to disclose or to suggest the use of DAG's as defined by Claims 1 and 19, and these rejections should be withdrawn. Likewise, Claims 2-3, 6-12 and 20-25 should also be allowable, at least as depending from an allowable base claim. Claims 14 and 15 define similar limitations, and should also be allowable.

Further with respect to Claims 6, 18 and 23, Delleart teaches away from calculation of an exact Hessian, or guiding a solution using Newton's method. Instead, Delleart proposes using a sparse solver technique or Levenberg-Marquardt approach for error minimization. See pages 203-205. Delleart and others of ordinary skill would have regarded computing the full Hessian and employing Newton's method at best as

an inefficient, slow solution technique. For this reason, the prior art consistently teaches avoiding computation of the full Hessian. The present invention contradicts conventional wisdom to provide an efficient solution using generic programming and automatic differentiation. Claims 6, 18 and 23 should therefore be allowable, for this additional reason.

With respect to Claims 3, 13, and 25, Delleart fails to disclose or suggest placing a camera supplying photogrammetry data *within* a three dimensional scene to be modeled. Applicant believes that such steps were avoided in prior-art photogrammetry, because data from cameras within the scene made solutions too difficult using prior-art solution techniques. Whether or not the general mathematical approach taught by Delleart or others is, in hindsight, theoretically capable of handing data from cameras placed within a scene is not relevant. The relevant fact is that cameras were traditionally always placed *outside* of the scene to be modeled. Indeed, Delleart discloses no example or suggestion of using photographic data collected inside of a scene for photogrammetry. Claims 3, 13, and 25 should therefore be allowable for this additional reason. Claims 14-17 should further be allowable, at least as depending from allowable Claim 13.

In view of the foregoing, the Applicant respectfully submits that Claims 1-3 and 6-25 are in condition for allowance. Reconsideration and withdrawal of the rejections is respectfully requested, and a timely Notice of Allowability is solicited. If it would be helpful to placing this application in condition for allowance, the Applicant encourages the Examiner to contact the undersigned counsel and conduct a telephonic interview.

To the extent necessary, Applicant petitions the Commissioner for a one-month extension of time, extending to July 15, 2005, the period for response to the Office Action dated March 15, 2005. A check in the amount of $120.00 is enclosed for the one-month extension of time pursuant to 37 CFR §1.17(a)(1). The Commissioner is authorized to charge any shortage in fees due in connection with the filing of this paper, including extension of time fees, to Deposit Account No. 50-0639.

Respectfully submitted,

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